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Investigating Student Talk for Productive Disciplinary Engagement During Remote Access to an Analytical Instrument

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ABSTRACT

This study investigated types of student engagement evident in discourse between students and facilitators in a grade eight class during their participation in a remote laboratory activity accessing an analytical instrument in a university chemistry laboratory from their classroom using the internet. Students were divided into six groups of three for the activity and their conversations with facilitators were video and audio recorded. Interaction analysis indicated occurrence of types of engagement as defined by the productive disciplinary engagement model and frequencies were determined. Results indicate that groups differed in the levels and types of engagement that they demonstrated. Pearson correlations demonstrated a significant positive relationship between engagement and student talk, and engagement and facilitator talk. Two groups demonstrated movement toward productive disciplinary engagement. Conversation analysis of these two examples suggests that dialogic interactions with a facilitator may be helpful in supporting students moving towards productive disciplinary engagement.

Keywords: remote laboratories; engagement: productive disciplinary engagement; discourse analysis; conversation analysis; dialogic interactions.

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CHAPTER 1. Introduction

A common goal of most educators is to enhance student engagement in the classroom, as a way to heighten meaningful learning. There is a long history of research establishing the link between student engagement and student learning (e.g. Christenson, Reschly & Wylie 2012; Finn & Zimmer, 2012; Balfanz, Bridgeland, Bruce & Hornig Fox, 2012) and the definition of student engagement has evolved over time (Reschly & Christenson, 2012). Newmann (1992) defined student engagement as:

> the student's psychological investment in and effort directed toward learning, understanding, or mastering the knowledge, skills, or crafts that academic work is intended to promote (Newmann, 1992, p. 12).

Recent models of engagement include academic engagement, social engagement, cognitive engagement, and affective engagement (Finn & Zimmer, 2012). Academic engagement describes behaviours linked to the learning process, social engagement depicts the degree to which a student follows classroom rules and norms, cognitive engagement is the amount of processing energy required for understanding; and affective engagement refers to an emotional response that is illustrated by how the student feels involved in school and the classroom (Finn & Zimmer, 2012). The word engagement is often used between educators as a generalization which encompasses academic, social, cognitive, and affective engagement.

Conversely, the impact of student disengagement has been identified as a contributor to student dropout rates and may be considered more concerning than school and class achievement outcomes (Finn & Zimmer, 2012; Balfanz, Bridgeland, Bruce &

Hornig Fox, 2012). Disengaged students can be well-behaved, attend class, and hand in assignments; however, they do not indicate that they are excited about the curriculum being presented, nor are they proud of any evidence of success within the content (Newmann, 1992). Identifying the impacts of disengagement within a classroom highlights this as a problem to be addressed by educators and demonstrates the importance of increasing student engagement. Educators are continually challenged to increase student engagement in the classroom by creating meaningful learning experiences in order to increase overall learning in their respective disciplines (Finn & Zimmer, 2012; Balfanz, et al., 2012).

In the field of STEM education (science, technology, engineering, and mathematics), observations internationally have described a decline in student interest and engagement in STEM courses in high school and a decline in the proportion of students choosing science and technology courses at the post-secondary level (OECD, 2008). A concerning outcome from this observation is the decrease in the number of students interested in continuing an education which leads toward a STEM-oriented career (OECD, 2008). The subsequent aftermath may lead to a bottom up effect where the decrease in students taking STEM courses will lead to a lack of experts within the respective disciplines of STEM. Promoting STEM content in elementary and middle schools, can result in students developing and maintaining engagement, as well as a positive attitude toward and interest in STEM topics (OECD, 2008; Christensen, Knezek & Tyler-Wood, 2015). Educators need to develop and implement a variety of activities and projects that promote student engagement in STEM. Students provided with the opportunity for more engaging, hands-on, active learning opportunities in STEM courses are more likely to continue on in those subjects in their high school years (Christensen et al., 2015; Moye, Dugger, & Starkweather, 2014; 2016). Integrating technology and real-world relevance into the content has been useful to promote STEM subjects and has fostered a positive interest in STEM content and careers (Christensen et al., 2015; Kennedy & Odell, 2014). This study focuses on engagement of middle school students in a STEM subject, specifically within the discipline of chemistry, when students are involved in a remote laboratory activity that is part of an inquiry-based project.

Remote laboratories activities allow students remote access to, and control of equipment, such as an analytical instrument, via the internet (Ma & Nickerson, 2006). They can serve as an opportunity for students to gain hands-on experience and use advanced technology while using the scientific inquiry approach (Lowe, Newcombe & Stumpers, 2013). Little research has been conducted around providing access for middle school students to a remote laboratory (Lowe et al., 2013). The context of this study is an opportunity that provides middle school students access to advanced scientific analytical equipment through partnership with the British Columbia Integrated Laboratory Network (BC-ILN). The BC-ILN has been providing post-secondary and high-school students with the opportunity to use analytical chemistry instruments for about ten years (BC-ILN, 2018). By creating a platform where middle-school students are able to access and use analytical equipment from their classroom, we propose that the BC-ILN can generate an opportunity to increase the engagement of students in this age group and facilitate a meaningful learning experience for them, through hand-on science activities, using online technology for real-life relevance.

This study follows a previous study which used student survey results to investigate evidence of engagement following their participation in a remote laboratory activity (Stewart, Lidster, Anchikoski, Cinel, Brewer, Rees, 2017). Results from student surveys demonstrated that students were engaged by the remote laboratory activity. The study that is the focus of this thesis aims to investigate this engagement further through analyzing discourse between students and facilitators during their participation in the BC-ILN remote laboratory activity. The purpose of analyzing discourse is to provide a direct view of engagement during the course of the activity. The study uses the model of productive disciplinary engagement (Engle & Conant, 2002) to categorize types of engagement. Students can be generally engaged through the activity (engagement); can demonstrate that they are engaged in the discipline on which the activity focuses (such as science); and ultimately, can exhibit productive disciplinary engagement, where the students show signs that they are moving ahead in their learning through their engagement.

The research question this study addresses is:

> In what ways are engagement, disciplinary engagement, and productive disciplinary engagement evident in student talk during the remote laboratory activity?

CHAPTER 2. Review of Literature

Engagement in STEM

For more than a decade, a decline in student interest in STEM (science, technology, engineering, and mathematics) courses has been observed internationally (OECD, 2008). As a result, there has been a decrease in the number of students pursuing careers in respective STEM fields (OECD, 2008). This is concerning when there is evidence that most students have a positive association with sciences in their early years (DeWitt, Archer, &, Osborne, 2014; Riegle-Crumb, Moore, & Ramos-Wada, 2010). Students typically become less interested in STEM courses by the time they reach middle school (or earlier) (DeWitt, et al., 2014; Sadler, Sonnert, Hazari, & Tai, 2012; Martinez & Guzman, 2013). Students in their early adolescence have higher psychosocial needs and are susceptible to the dispositions of the adults and peers in their life (George, Stevenson, Thomason, & Beane, 1992). The psychosocial needs, socioeconomic status, and dispositions of those in their environment in turn may have an effect on the outcome of the student's perceptions of STEM disciplines. Career interests of students entering high school are strong predictors of their career interests and goals leaving high school (Sadler, et al., 2012). This suggests that the experiences, socialization, and characteristics of individuals during middle school will impact their long-term career intentions. In order to address the decrease in student enrollment in STEM courses which the OECD report (2008) describes, it is essential to support student engagement with engaging content in STEM courses during elementary and middle school years.

Student engagement refers to a students' involvement and attentiveness during learning activities, as well as how connected they are to their peers, classes, and school

(Axelson, & Flick, 2011). Building awareness of student engagement levels can help educators understand and improve student outcomes (Finn, & Zimmer, 2012). Engagement in STEM denotes student engagement with respect to STEM content and within STEM courses. Christensen et al., (2015) point out that students who have opportunities for more engaging, hands-on, active learning opportunities in STEM courses are more likely to continue in these subjects in their high school years. It is essential to encourage real world relevance in order to promote STEM programs, and a positive interest in STEM content and careers (Christensen et al*.,* 2015). Creating engaging activities which contain real world relevance is important for elementary and middle school educators in order for students to maintain an interest in STEM courses.

Research has demonstrated there are several ways to increase engagement in a science classroom. Moye et al., (Sept. 2014) explained how “the act of doing was essential for survival and drove the evolution of technology” (p. 24). Schwichow et al., (2016) demonstrated the importance of hands-on and paper-and-pencil experiences. Students who gained more hands-on experience were better at hands-on tasks, whereas the group that performed more paper-and-pencil tasks, such as creating a poster board, were better at accomplishing paper-and-pencil tasks (Schwichow et al., 2016). The MUSIC model of motivation was also effective among many disciplines where “students are more motivated when they perceive that (a) they are eMpowered, (b) the content is Useful, (c) they can be Successful, (d) they are Interested, and (e) they feel Cared for by others in the learning environment” (Jones, et al*.,* 2015 p. 405).

The overview of the literature regarding engagement highlights the complexity of the term engagement and how it is defined in various ways (Groccia, 2018). One perspective which encompass many of the descriptions of engagement is the multidimensional perspective by Groccia (2018). In his paper, Groccia explains how the multidimensional perspective on engagement would promote teachers to engage students across a variety of disciplines in such a way as to address genuine problems, allowing students to use curricular content to solve those problems which would lead to “intellectual growth and a heightened sense of personal responsibility” (Groccia, 2018). Another perspective that is an inclusive view of engagement is the holistic perspective of engagement. Kahu (2011) explains engagement as a dynamic continuum which includes several areas such as content, classroom and school. Since engagement is holistic and includes several locations, it is “best understood through in-depth qualitative work” (Kahu, 2011). These two perspectives of engagement are evident in the teaching and research described in this study.

The current generation of learners encompasses generation Z, including individuals born in 1995-2012 who learn and study in a different way than previous generations (Holubova, 2015). With different learning and study modes, it appears that this diverse generation requires a diverse range of activities to achieve engagement in the classroom. In a study completed by Holubova (2015), a variety of strategies were implemented including: problem-based learning, project-based learning, team work, inquiry-based learning, interdisciplinary approaches, and experiments that included low cost as well as computer-based experiments and remote laboratories. A suggestion by Kennedy and Odell (2014) is to integrate technology in the classroom, which is an integral aspect of the current generation’s education and may increase student engagement in STEM. Holubova’s (2015) findings supported the importance of technology by demonstrating that students were motivated to study physics when they were given the opportunity to utilize modern information technology such as computers, internet, and mobile phones. This demonstrates the necessity of implementing technology in a classroom to produce engaged learners. By extension, utilizing remote laboratories have the potential to enhance student engagement in STEM content areas.

Inquiry-based and project-based learning can also increase engagement (e.g. Holubova, 2015). Curricula within public education in British Columbia has been recently reformed, encouraging BC educators to shift teaching practices to an inquiry- and project-based model (British Columbia Ministry of Education, 2012). Providing inquiry investigations supports students in developing a greater understanding of scientific concepts – just one benefit of the inquiry – and project-based approach in science education (e.g. Harlen, 2018; Polman, 2000), which has been adopted and implemented globally (AMGEN, 2016; Next Generation Science Standards, 2013; Tytler, 2007; Rocard report, 2007). Science inquiry has been utilized since the 1960s and persists within education as it fosters learning of scientific processes (e.g. Harlen, 2018). Inquiry-based learning provides students the opportunity to deliberate over, question, and analyze observations or information within disciplinary content. Problem-based learning, similar to the scientific inquiry model, has also been shown to be effective at producing learners who are well motivated, independent, and effective problem solvers (Belt, Evans, McCreedy, Overton, & Summerfield, 2002). Educators are using innovative approaches to inquiry- and project- based learning. For example, in a study conducted by Belt, et al., 2002, students investigated a fictitious murder case and used their knowledge of analytical chemistry and forensic science to solve the case. The survey results from this problem-based activity demonstrated that overall students enjoyed the activity and therefore were engaged (Belt, et al., 2002).

The remote laboratory activity that is the focus of this study was conducted in the context of a similar innovative cross-curricular plan that brings together English language arts, humanities, and science through inquiry -and project - based learning. One driving question of the class inquiry is "how can potable water be accessed in an off-the-grid community?" Through this question, students were provided with the opportunity to hypothesize where along a river would be an ideal location for a community to form. Students were able form a hypothesis given the activities occurring at each site which could affect the levels of nitrogen in the water (e.g. small farm, large farm, waste water treatment plant). To assist in determining the location of the community, students were provided access to a remote laboratory to analyze pre-made water samples, possessing varying levels of nitrogen, to simulate the activities happening at the sites along the river.

Remote Laboratories

Remote laboratories allow access to laboratory equipment to individuals located in a different geographic area than the equipment itself. Permitting access and control of real laboratory equipment distinguishes remote laboratories from virtual laboratories, where simulations of equipment would be used. A variety of remote laboratories have become available, the majority of which allow individuals to access and control analytical equipment via the internet (Ma & Nickerson, 2006; Crippen, et al., 2012). The common outcomes of remote laboratories are supporting higher education institutions in classroom delivery and providing a platform for resource sharing among institutions (Ma & Nickerson, 2006; Crippen, Archambault & Kern, 2012).

Universities and colleges recognize the applications of remote laboratories, and in this context, these remote laboratories are becoming popular internationally (Ma & Nickerson, 2006). In Europe, remote laboratories have been utilized at the university level in the areas of engineering and physics to offer students a feasible and practical portion to their course work (Lang, Mengelkamp, Jagar, Geoffroy, Billaud, & Zimmer, 2007; Axaopoulos, Moutsopoulos & Theodoridis, 2012). Australian researchers Lowe, Newcombe, and Stumpers (2013), have studied remote laboratory access for secondary school science education. From the survey results, Lowe et al., (2013) concluded that students felt that collecting data from the laboratory was user friendly. However, overall students had a preference for traditional laboratory activities which they can complete in the classroom, conducting the experiment with their hands and not through a computer. In northern British Columbia (B.C.), an undergraduate biochemistry lab-based course used a remote lab located in the interior of B.C. to observe how bioinorganic chemistry concepts applied to biochemistry (Erasmus, Brewer, & Cinel, 2014). Through the Monterrey Institute of Technology and Higher Education located in Monterrey, Nuevo León, Mexico, instructors used a remote lab as a visual demonstration tool for their classes (Ramirez, Soledad, & Marrero, 2016). In the United States, researchers detailed the experience and perspective of thirty-five secondary teachers across fifteen U.S. states teaching online courses (Crippen, et al., 2012). The outcome of this study described how remote laboratories could be a beneficial tool when administering distance education (Crippen, et al., 2012). Educators and students recognize the importance of a skill set acquired through real laboratory experiences, and remote labs present a suitable solution to provide a laboratory experience when completing science courses through distance education (Gillet, Latchman, Salzmann, & Crisalle, 2001; Alhalabi, et al., 1998; Schaur, et al., 2008).

It has been demonstrated by Corter (2011) that when remote laboratories are used effectively, they can be a valuable resource which provide students with similar outcomes as a traditional hands-on laboratory. The effective use of remote laboratories as an alternative to hands-on laboratory methods has been supported through the bibliometric analysis of Heradio (2016). Additional outcomes with remote laboratories are achieved from students utilizing the actual physical apparatus, with which they obtain real data in real time (Heradio, et al., 2016; Corter et al., 2011). In their concluding remarks, Schaur, et al., (2008) described how they believe remote laboratories make engineering and science more interesting and engaging, which in turn, can encourage students to become more pro-active in their understanding of real-world phenomena. In the study conducted by Erasmus et al., (2014), university students located in northern B.C. were able to access analytical equipment located in the interior of B.C., through the remote BC-ILN laboratory. With access to the remote laboratory in the B.C. interior, students in northern B.C. were provided with an opportunity to gain experience running an analytical instrument that was not previously available to them (Erasmus, et al., 2014). The conclusions from this study demonstrated that the students enjoyed the remote laboratory experience and felt it was valuable (Erasmus, et al., 2014).

A review of the literature demonstrates that remote laboratories are rarely used as frequently or in the same fashion in high schools and middle schools as they are among universities and colleges. A study conducted by Crippen (2012) describes how remote laboratories are used by secondary science classes to facilitate online courses. Whereas, the Australian researcher, Lowe (2012), has the only publication with participants as young as 13 years old utilizing a remote laboratory. Universities and colleges are the prevalent demographic using remote laboratories since the output of equipment being used requires a higher level of understanding of theories and principles (Lowe, et al., 2013). Lowe believes that the operator of the equipment requires a higher educational background to implement and understand the output of the equipment itself (Lowe, et al., 2013). The BC-ILN has been providing access to analytical instrumentation to high schools in the BC interior for the past seven years. In 2012, as a teacher, I coordinated with the BC-ILN to offer my students an opportunity to use chemical instrumentation that would not be accessible in their school. I wanted to provide a real-world, hands-on experience, and to demonstrate that success in the chemistry field is attainable. This experience with the BC-ILN inspired me to investigate whether evidence of engagement in chemistry is present while students use a remote laboratory. I became involved in this research study as there is an apparent gap in the literature regarding the effectiveness of remote laboratories facilitating science courses with students in middle school. This study is the unique in that it is the first-time middle school students complete a chemistry experiment accessing an analytical instrument remotely. Specifically, students determined total nitrogen content of river water samples via a Shimadzu Total Organic Carbon (TOC)/Total Nitrogen (TN) Analyzer, controlled by a computer connected to the internet.

Evidence of Engagement through Analysis of Classroom Talk

Many studies of student engagement use surveys and interviews to find out, after the fact, students' opinions of their own engagement, and teachers' opinions of students' engagement. Another way to analyze student engagement is through observation of classroom talk in recordings collected while lessons and activities are actually going on. Student engagement can be evident in what students say during teacher-student and student-student interactions when they are in the midst of activities and lessons. Evidence shows that students need plenty of opportunity to talk about their work in the classroom and when students are engaged, this is apparent in the amount they have to say and the ways in which they speak (Cazden, 2001). In this section, literature on the study of classroom talk will be reviewed.

As recording technology developed throughout the years, classroom discourse became a major focus of study (Mercer & Dawes, 2014). Encouraging student discourse in the classroom is important and when doing so there are many factors influencing the amount of student dialogue occurring. The discourse leading up to, the type of, and the nature of a specific activity can affect a student's response, inadvertently demonstrating the student's knowledge (Mehan, 1979). Teacher's preference toward a certain teaching strategy can influence their discourse with their students and can highlight the difference between the teacher and student knowledge (Mercer & Dawes, 2014). Educators who are willing to change their teaching style and strategies by using different activities and resources can ultimately encourage more discourse in the classroom (Cazden, 2001). School climate and culture also influence the teacher, who can embody these values and impact students that do not associate with or believe in the values of the school, impeding students' participation, learning and active dialogue in the classroom (Brown, 2004). In recent years, science inquiry methods have focussed on becoming more student-centred by encouraging classroom discourse and offering sufficient opportunities for articulating thoughts (Rocard report, 2007; Tyter, 2007).

Teacher discourse and dialogue with students in the classroom can influence classroom structure, dynamics, as well as how and when students participate in dialogue. Well-developed teacher questions and the dialogue of the teacher to the students, can aid in children's learning and development of their own use of language as a reasoning device (Mercer & Dawes, 2014). Teachers influence student dialogue within the purpose of their questioning. Timing of a question, current knowledge of the topic, as well as teacher dialogue with the students affects student responses to the question and the meaning and function of the question itself (Mercer & Dawes, 2014). To increase student dialogue in a classroom, an educator must be actively encouraging and seeking out students' responses (Mercer & Dawes, 2014). Teachers who reinforce students' ideas in their own descriptions, ask open-ended questions, and intentionally abstain from providing an evaluative feedback comment to promote student discourse and dialogue in the classroom (Mercer & Dawes, 2014). Brown (2004) observed that students take one of four statuses toward science discourse: opposition status, maintenance status, incorporation status, and proficiency status (Brown, 2004). Students displaying opposition status avoided science discourse (Brown, 2004). Maintenance status students maintained their regular discourse behaviour, despite demonstrating the use science discourse (Brown, 2004). Students displaying incorporation status tried to incorporate science discourse into their normative discourse, whereas those exhibiting proficiency status applied scientific discourse fluently (Brown, 2004). Characterizing student status within science discourse demonstrates the importance of teacher discourse and integrating science discourse into the classroom. Students that demonstrate incorporation status may be more engaged students, therefore may find science more enjoyable and pursue science-related courses in the future. It is the responsibility of the educator to recognize the importance of classroom dialogue and facilitate ways to promote and build it within their own classroom (Brown, 2004).

Interactions between students are known to play a significant role in successful outcomes in school socialization and healthy development (Johnson, 1981). Dialogue between students presents another avenue for students to articulate common knowledge they possess by using science terminology in the correct context. During dialogue between students, each individual must actively make decisions while listening to their peer since a peer in the classroom may not be perceived as an equally credible resource to knowledge of the teacher. Therefore, throughout student dialogue, individuals must consider the source of the information and be able to apply their own experiences and knowledge to infer whether the information seems credible and how to construct a counterargument, if there is a disagreement. Argument is a critical aspect of science discourse in a classroom and can be used as a tool to engage learners, enhance scientific thinking and reasoning, and assist in clarification of previous knowledge (Osborne, Erduran, & Simon, 2004; Cavagnetto, Hand, & Norton-Meier, 2009). Working in small groups with peers offers more opportunities to practice and utilize scientific argumentation and helps develop students' understanding of concepts (Crawford, Kelly, & Brown, 1999). Students appreciate and find the collaborative aspects of group work to be rewarding as they are working together to accomplish a common objective (Wells & Arauz, 2006). It is important for educators to recognize their instrumental role in the classroom and understand how aspects of their teaching strategies will influence student-student interactions and dialogue in their classroom (Cavagnetto, Hand, & Norton-Meier, 2009).

Conversations and language make up the majority of transactions and communications in a school. Therefore, analyzing dialogue in the classroom has been used to identify the quality of classroom discourse, highlight areas where student learning can increase, and determine if student learning is occurring (Wells & Arauz, 2006). Educators of university students have analyzed dialogue in their classrooms as an evaluation to ensure professional accountability, accountability to the traditions of the discipline, that the community of inquiry they facilitate continues to be self-regulative and self-correcting (Laverty & Gregory, 2007). By recognizing thematic patterns through dialogic analysis, a different view of classroom dynamics and student learning is presented (Lemke, 1990). A variety of discourse forms exist, all of which serve a place and purpose to enhance student learning (Scott, Mortimer & Aguiar, 2006). Students who are given active roles in which they maintain participation in classroom dialogue will accomplish the best educational results (Cazden, 2001; Mercer & Dawes, 2014).

It has been possible to identify common patterns in classroom discourse. Early studies showed that the most common classroom discourse pattern was the initiation, reply, and evaluation form (I-R-E) (Mehan, 1979). It was determined that during this type of discourse, the teacher monopolized two thirds of the dialogue (Mehan, 1979; Cazden, 2001). The I-R-E form appeared to restrict students from speaking openly in a classroom and prevented choice of when to speak, creating obstacles for student learning (Cazden, 2001; Mercer & Dawes, 2014). When students and teachers were talking more freely and naturally other patterns involving feedback such as I-R-F-R-F-R-F (Initiation – Reply – Feedback), became evident in the classroom, and such patterns developed when teachers were using more open-ended questioning (Mercer & Dawes, 2014; Alexander, 2010).

The chains of interactions that include feedback turns from the teachers and further responses from the students exposed through analyzing classroom dialogue and dialogic teaching, identify where student learning takes place (Alexander, 2010). Dialogic analysis requires pragmatic analysis of transcripts where consideration of the choice of words used, connotation of voice, and context of conversation can be examined to demonstrate if learning has occurred. In many cases, a teacher will ask students questions as a form of evaluation of student knowledge; though this may not demonstrate learning is occurring in the dialogue, it may demonstrate that learning has occurred since there is a demonstration of knowledge being presented. Student discourse and questions to peers and teacher may indicate a level of engagement of the student and, depending on the question being asked, potentially demonstrate the student’s willingness to learn. An important aspect of student learning is creating an environment that supports student discourse in the classroom (Alexander, 2015; Cazden, 2001; Mercer & Dawes, 2014). When students feel comfortable and supported within their environment, learning is increased and may likely be indicated through student dialogue.

Some researchers including Alexander (2015) and Mercer and Dawes (2014) believe that student engagement, and learning will only occur when students have opportunities for dialogue. This stems from Vygotsky’s (1978) philosophy of learning, where student learning is seen to occur through interactions, primarily student discourse.

In this study, the dialogue between students and facilitator was examined for evidence of engagement.

Productive Disciplinary Engagement Model

An effective way to determine student engagement is by analyzing student discourse throughout activities (Engle & Conant, 2002). Engle and Conant (2002) divide student engagement into three main categories or levels: engagement, disciplinary engagement, and productive disciplinary engagement where all three categories are within the general description of engagement. In the following sections their categories and guiding principles are described.

Engagement

Teachers continually assess the amount of student engagement in their classroom by being cognisant of how actively students are participating, as well the proportion of students participating. Student contributions in the classroom can also impact the engagement of other students in the class. Large-group student-led discussions can enable opportunities for more students to contribute, which may enhance participation by other students. Body language, and where students' move, and focus their eyes are also indicators that educators often use to assess the level of engagement of students. Many teachers have witnessed an apparent, and sometimes spontaneous reengagement of students throughout an activity. Conversations and words can be interpreted differently among cultures and contexts (Engle & Conant, 2002).

Disciplinary Engagement

Disciplinary engagement implies the engagement of the students is in the context of the discipline (such as science) they are working on at that time. Educators may have different opinions on how students should interact with the discipline and how the discourse should unfold in the classroom when involved with the discipline. It is important that the evidence of disciplinary engagement links to what students are doing or saying about the discipline being taught. Some educators may view disciplinary engagement as students being on task during an activity and completing requested disciplinary outcomes in a timely manner.

Productive Disciplinary Engagement

The final type of engagement in the productive disciplinary engagement model describes engagement as being productive within the discipline. Productive disciplinary engagement demonstrates an educator’s goal for their students; students’ being able to utilize their knowledge in the discipline in a productive way that shows intellectual progress (Engle & Conant, 2002). The progress students make toward productive disciplinary engagement includes: solving new problems, making novel associations, and distinguishing misconceptions to ask questions for further analysis (Engle & Conant, 2002). Progress toward productive disciplinary engagement will vary for each student and may take time. Evidence demonstrating students’ intellectual progress in the discipline is important and displays success for students’ obtaining a deeper level of learning. Engle and Conant (2002) propose that when educators set up their classroom as proposed by the PDE model, they will witness moments of students elaborating on ideas and their understanding of the discipline will be demonstrated as it occurs in their everyday classroom situations.

The modes of the productive disciplinary engagement model can be identified and described as separate entities that all contribute to the larger outcome of deeper, meaningful student learning. Though each stage can be identified separately, one can also view this model as a continuous journey through each stage. Each stage of the model leads toward the next and is necessary in order to establish the next stage, which exhibits intellectual progress in a discipline. One goal of the proposed research is to identify how engagement can lead toward disciplinary engagement, and therefore onto productive disciplinary engagement in an activity utilizing a remote laboratory.

Guiding Principles of Productive Disciplinary Engagement

In order to achieve the outcome of meaningful learning and creating a community of learners through the productive disciplinary engagement model, Engle and Conant (2002) propose four guiding principles that foster PDE. They propose that these principles aid in supporting students in the journey to establishing intellectual progress. The four guiding principles of PDE are problematizing, authority, accountability, and resources (Engle & Conant, 2002).

Problematizing

Productive disciplinary engagement is fostered when students are provided with an opportunity to problematize the content presented to them. Students need to have opportunities to tackle intellectual problems that for them are advanced. Educators can facilitate problematizing content by creating an environment where students are encouraged to ask questions, convey their own proposals, as well as express their challenges (Engle & Conant, 2002). Students should be able to naturally problematize their area of study and identify problems that interest them. When teachers are able to present problems that promote student inquiry and stimulate sense-making skills, they provide an opportunity for their student to grow as a community of learners and to become engaged with the content (Engle & Conant, 2002). Problematizing content encourages students to embrace intellectual challenges and problems themselves. The problems students are able to identify may not be seen as problems from the eyes of an expert, the importance is their perspective or their interpretation (Engle & Conant, 2002).

Authority

Offering occasions for student to have authority allows students to become engaged and provides an avenue which may lead toward productive disciplinary engagement. In order to facilitate student authority, the students must be given an active role within the activity to identify problems and contribute to problem solving (Engle & Conant, 2002). Educators must assist in developing student authority by acknowledging student ideas and contributions to the entire student body; identifying the students as an integral part of the classroom community. To increase student authority, students can be placed in a collaborative role to contribute to the learning of the classroom community. Student engagement will increase when the students are able to view themselves as contributors to a project. If students are able to recognize the importance of their contributions, the student body will develop into a community of experts. Fostering student authority should support all students in taking ownership of their work, ideas, and questions (Engle & Conant, 2002).

Accountability

Student accountability is described as an internal process where students are able to impact the learning of their class through accountability towards their contributions as a response to the products of peers within their classroom (Engle & Conant, 2002). Student authority and student accountability are related and highlight each other when fostering a classroom toward productive disciplinary engagement. Students who have authority over their intellectual product may also be held accountable to the overall group. Students understand what they produce will be held to the disciplinary norm of the content within and outside of their classroom community. The teacher and other students in the learning environment promote an atmosphere which encourages students to produce work and information that makes sense and is reliable in the content being learned, thus producing a classroom of experts within the area of the discipline. The accountability implied ensures that students will consult many resources, including peers and teacher, in order to formulate their own understanding of the topic and will not discount applicable information within the area without validation (Engle & Conant, 2002). This promotes acceptance of classroom and disciplinary norms, since students are not required to accept content from other areas. However, it is essential for them to be responsive to the ideas and content (Engle & Conant, 2002). Providing students with the opportunity to contribute to a collective project through problem solving, enables them to acknowledge how the contributions they make can have significant implications to the overall project (Wells & Arauz, 2006).

Resources

Providing access to relevant resources is a critical piece for the success of students in demonstrating the attributes of the principles of productive disciplinary engagement (Engle & Conant, 2002). Relevant resources can act as the starting point for students to problematize the content, produce material for which they are accountable, and maintain authority. The dynamic of each classroom and each student will possess different needs and, consequently, resources in order to support productive disciplinary engagement in the learning environment. For some students, a resource of time will be valuable to explore particular questions, problems, or projects in depth. Other students may require additional resources, which provide further information relevant to the students' areas of study and foster student discourse around problematizing content (Engle & Conant, 2002). Resources that promote student authority and accountability may include opportunities for engagement through public forums and providing access to experts within the field of study (Engle & Conant, 2002). In order for the relevant resources' principle of productive disciplinary engagement to be effective, the resources must be accessible and attainable for the educator to distribute to their students.

Enhancement of productive disciplinary engagement will be observed when the four guiding principles are fostered effectively. Implementing any of these guiding principles will help create a successful learning environment for students and will increase the engagement within the class. A fundamental component to the success of the four guiding principles is maintaining an environment of respect where all individuals involved (teachers and students) are viewed as equally respected contributing peers (Engle & Conant, 2002). This research will outline whether the four guiding principles of productive disciplinary engagement are embedded within an activity utilizing a remote laboratory.

Theoretical Framework: Using the Productive Disciplinary Engagement Model

In this study the productive disciplinary engagement model was used as a research lens, analyzing student discourse to determine whether engagement was present in the classroom and to classify the engagement throughout student discourse (Engle & Conant 2002). As described above Engle and Conant (2002) divide student engagement into the three main categories: engagement, disciplinary engagement, and productive disciplinary engagement where all three categories are within the general description of engagement (See Figure 1).

Figure 1. The Productive Disciplinary Engagement Model.

Figure 1. The figure indicates the inclusive nature of the terms Engagement and Disciplinary Engagement in the theoretical framework of Productive Disciplinary Framework (Engle & Conant, 2002).

In order to use productive disciplinary engagement as the theoretical framework, each type of engagement needed to be clearly defined. In this study, engagement is an inclusive, overarching term which is present when students demonstrate signs of disciplinary engagement, as well as productive disciplinary engagement (see Figure 1). “Engagement” was defined as a turn, in the turn-taking routine of dialogue (Sacks, Schegloff, & Jefferson, 1974) related to the assigned task of analyzing their river water sample, or fragments of conversations with peers, and or, facilitator that do not directly involve the task at hand, though the task itself may initiate the talk. Two types of "Disciplinary Engagement" were defined, "Disciplinary Engagement in Science" and "Disciplinary Engagement with Technology". "Disciplinary Engagement in Science" was defined as turns of student conversation that were specifically in the context of the discipline of science, or turns where students demonstrated attributes of a person practicing science. "Disciplinary Engagement in Technology" was defined as students engaged in the technology (such as tablet, or Skype) of the activity by demonstrating interest in the technology which facilitates the activity. A student demonstrating signs of productive disciplinary engagement would exhibit signs of disciplinary engagement in science as well as engagement, and therefore a turn would be counted as all three types of engagement (See Figure 1). "Productive Disciplinary Engagement" was defined as, turns of conversation that demonstrated the student(s) being able to utilize their knowledge in the discipline in a productive way showing intellectual progress. Examples of "Productive Disciplinary Engagement" may include solving new problems, making novel associations, and distinguishing misconceptions to ask questions for further analysis (Engle & Conant, 2002).

When using the model of productive disciplinary engagement as a research lens, a researcher can examine the context of their study for the four guiding principles described by Engle and Conant (2002). Engle and Conant (2002) propose that students will be able to reach productive disciplinary engagement when problematizing, authority, accountability, and resources are evident (these principles are described in detail above).

Therefore, in this study the context of the study was examined for evidence of the four principles.

CHAPTER 3. Methods

Context

The context of this study was a cross-curricular inquiry project-based grade eight class focussing on the theme of "What Sustains Us" (Stewart, Lidster, Anchikoski, Cinel, Brewer & Rees, 2017). One of the inquiry tasks the teacher created was a real-world scenario where the class was to establish a location along a river for a hypothetical village as an off-the grid community. The challenge for students was to determine how this hypothetical community would be able to access potable water and where it should be established along the river. To support working through the class theme, a new interactive multiday student learning activity was created. This activity was modified from existing educational resources (Candow, 2013) developed with the BC-Integrated Laboratory Network (BC-ILN, 2018) and was named "Measuring the Total Nitrogen Content of River Water Samples". Seven different authentic sites were included in the activity along with their corresponding water samples. The water samples that represented the seven sites were synthetic, in that they were created in a laboratory setting. Research was conducted by the scientist creating the water samples to ensure that the levels of nitrogen represented the authentic levels of nitrogen which would exist at the various sites. This activity was adapted to meet the needs of the students in the cross-curricular inquiry class, allowing them to determine the total nitrogen content in the river water samples and provide evidence and support to address their class theme for the year. The "Measuring the Total Nitrogen Content of River Water Samples" activity provided students with enough background information on the effects of high nitrogen levels in the water, as well as factors influencing nitrogen levels, so students could research these topics further and answer questions they had generated earlier. The activity resources also included an interactive poster describing each site along the river. With their base knowledge of nitrogen in the water and the sites along the river, students were able to deliberate in small groups, hypothesize and make predictions regarding the rank of the seven sites from highest to lowest levels of nitrogen. The scenario with the community along with the river created provided a real-world inquiry task for the students. The BC-ILN provided the resource of the TN-analyzer, a real instrument located at the university to facilitate the class inquiry project. The students controlled the instrument and collected their data in real-time.

Set-Up

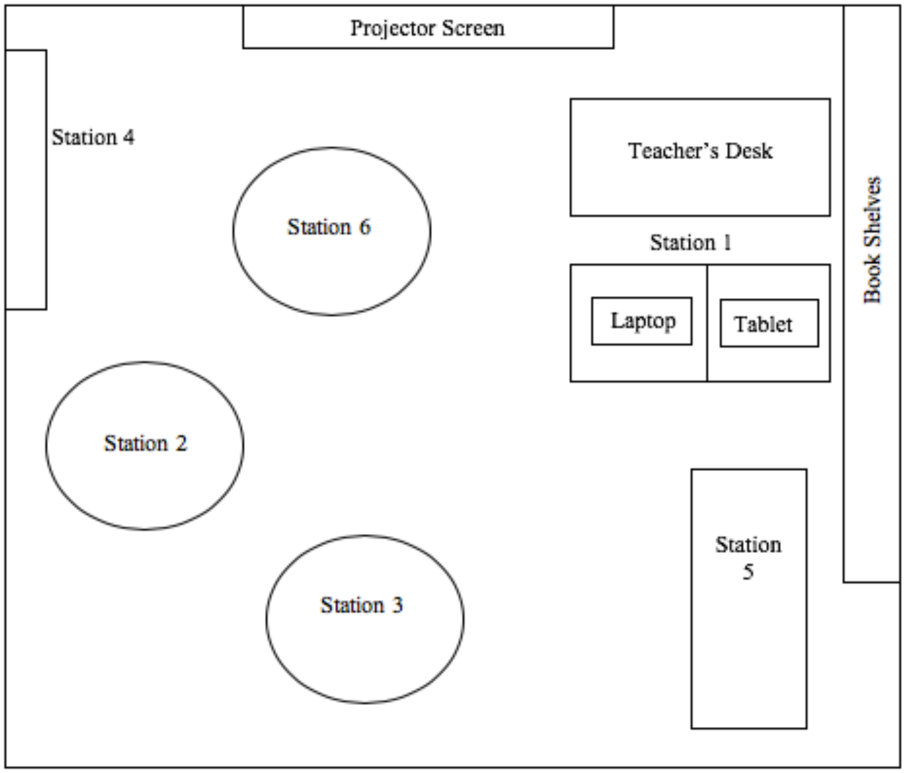
The teacher divided the students into seven groups, assigning each group a site along the fictitious river. The seven sites included: River, Campground, Big Farm, Little Farm, Construction Site, Waste Water Treatment Facility, and Creek. As a group, the students worked together to predict the rank of the seven sites from highest to lowest levels of nitrogen. The groups were also responsible for measuring the total nitrogen content at their assigned site and reporting their results to the class.

The classroom was set up into stations by the teacher, where "Measuring the Total Nitrogen Content of River Water Samples" was station 1 (Table 1 and Figure 2.). Each station facilitated the students' journey through a scientific inquiry process in determining where to establish a hypothetical village as an off-the grid community along the fictitious river.

Table 1. Student Activities at Stations in Classroom

Station	**Activity**
Station 1	Groups used the BC-ILN to test water samples and record TN results
Station 2	Groups added the results of their TN test to a large bar graph
Station 3	Students watched BC-ILN – A video tour of the Total Nitrogen (TN) Analyzer and answered questions about the instrument
Station 4	As data was collected and recorded, groups were given an opportunity to change their initial predictions
Station 5	Using Google Maps and their own knowledge of the rivers, students located an area along the river similar the site assigned to their group and labelled it on the map of the fictitious river
Station 6	Groups coloured clipart images to represent their site of the river on the bar graph, as well as on the map of the fictitious river.

Figure 2. Classroom set up and Station layout



Remote Laboratory Access

The analytical instrument the students accessed and controlled remotely to analyze the river water samples was the Shimadzu TOC/TN Analyzer which is controlled by a computer connected to the internet (Figure 3). Participants had control over the TOC-TN analyzer via the internet and were not using a simulation of the equipment; participants used a remote laboratory activity. Each group varied in the amount of time (12 to 14 minutes) to collect the data for their assigned river sample, as each set of students worked through the instructions to the instrument at different paces.

Figure 3. The Shimadzu TOC/TN Analyzer located at the University.

Figure 3. From left to right, arrows indicate the computer, the autosampler, and the analyzer.

Students were provided with a laptop containing the Teamviewer software, necessary software for remote access to the TOC-TN analyzer's computer (Figure 4). Through a live feed via a Microsoft LifeCam VX-1000 mounted in the instrument, students were able to see a close view of the interior of the instrument's autosampler carousel (Figure 5). Students were also provided with a tablet, which provided access to control a Canon VB-C50iR network camera mounted to the laboratory ceiling (Figure 4). This live stream feed from the ceiling camera offers students a more in-depth view of other aspects of the laboratory which houses the instrument they control.

Figure 4. The laptop and tablet students used at station one.

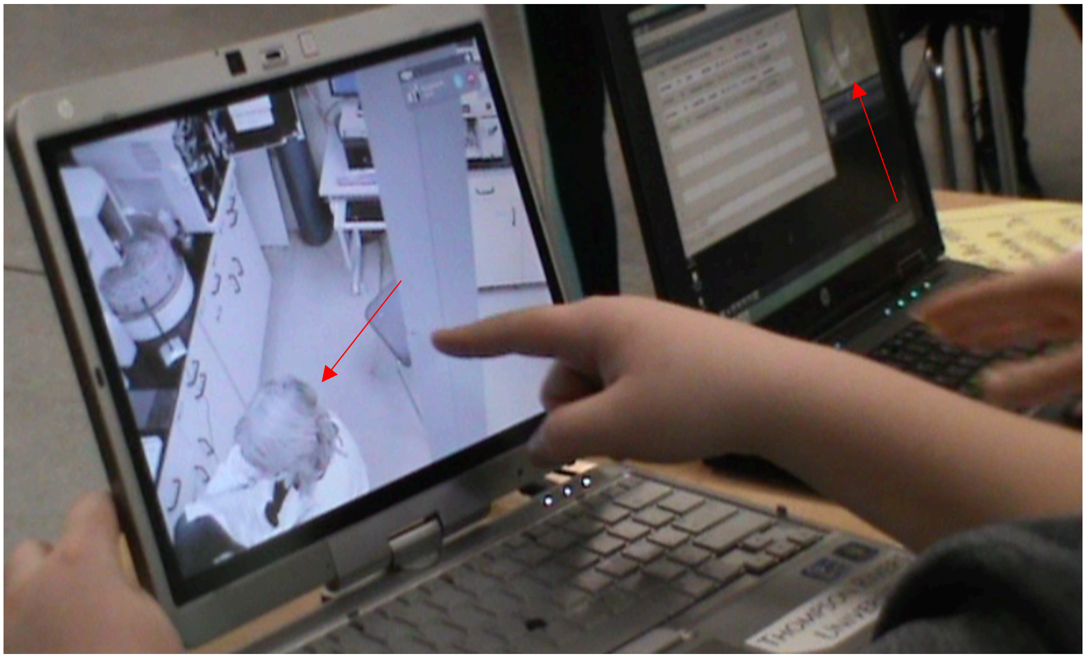


Figure 4. Right*:* The laptop controlling Total Nitrogen Analyzer's computer at the university. The video feed of the camera mounted in the autosampler carousel is shown on the laptop screen; Left: Tablet controlling camera mounted to the laboratory ceiling. The arrow points to Sara, the facilitating chemist, seen on the tablet screen, while she sits working in the laboratory at the university.

Figure 5. The instrument's autosampler carousel and the laptop showing the livestream video of the autosampler.

Figure 5. Left: The arrow indicates the camera mounted in instrument's autosampler carousel, which is in the chemistry lab. Right: The laptop, which is in the classroom, controlling Total Nitrogen Analyzer's computer. The arrow indicates the livestream video of autosampler.

Communication with a chemistry professor at the university was accessible to students, if needed, via Skype. Using Skype as a communication tool not only allowed communication but also students could also hear audio coming from the TOC-TN analyzer. In groups of three, students controlled the TOC-TN analyzer remotely by using written instructions that were provided on how to control the instrument. The students were able to observe the collection of data in real time as the computer generated the results of total nitrogen in their assigned river water sample. Throughout the remote analysis, students were able to communicate directly with a facilitator present with them, or with the chemistry professor located in the laboratory situated at the university. Students in each group were responsible for recording the results of their sample and reporting these results by including them in a graph combining class data collected by each group. The incoming data provided each group with the opportunity to revise their ranking predictions of the water samples based on actual results.

Research Methodology

This project investigated, engagement, disciplinary engagement and productive disciplinary engagement (Engle & Conant, 2002) by analyzing talk at station 1, the remote lab access station. The research question addressed was: In what ways are engagement, disciplinary engagement, and productive disciplinary engagement evident in student talk during the remote laboratory activity? In order to answer the research question, a mixed methods approach was taken. Interaction analysis (a qualitative method) was used to locate examples of each type of engagement. Quantitative methods were applied to determine frequencies of the types of engagement and correlations. Finally, the qualitative method of conversation analysis was used to examine the ways that different types of engagement transpired.

Interaction analysis is a methodology used to examine interactions that occur between individuals as well as the objects in their surroundings (Jordan & Henderson, 1995). Conversation analysis (Sacks, Schegloff, & Jefferson, 1974) involves more detailed analysis using detailed transcription (cf. Atkinson & Heritage, 1984). This included notation of the following: overlapping speech (and duration of overlap), intonation, pause (including duration), speech volume, and any non-verbal activity. In this study, interaction analysis and conversation analysis were applied to the conversations between students and facilitator as well as between students, and between students and scientist via Skype.

This research is fundamentally an action research study (Hinchey, 2008) in that I was the primary investigator and am within the community of science education and this study allows me to investigate my own practice as the facilitator of students' access and use of an analytical instrument remotely. Through this study, the findings will lead to an action, which will be to revise and improve a chemistry remote lab activity designed to enhance student engagement.

Participants

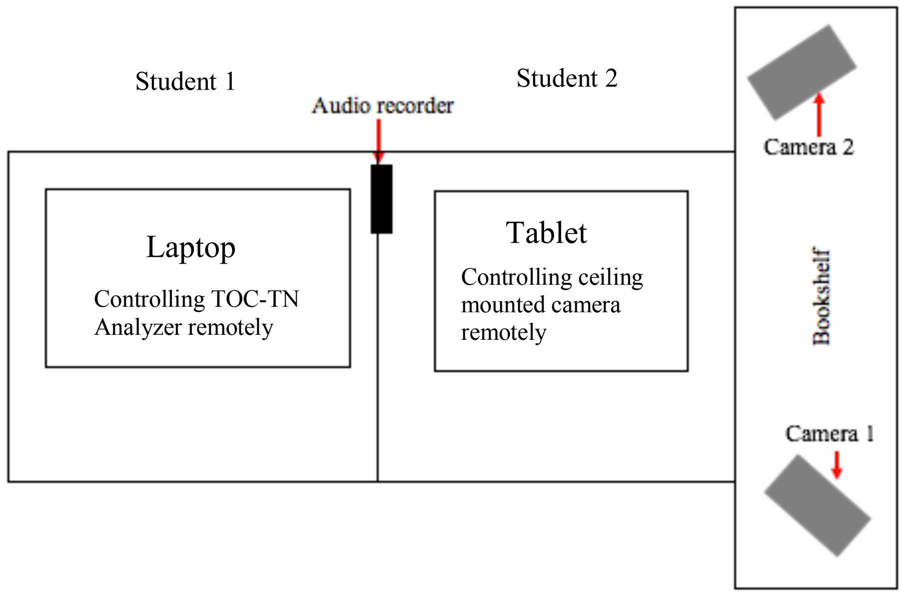
This cross-curricular inquiry class was part of a middle school within a low socio-economic area in a mid-sized city, located in the interior of British Columbia. All twenty-five students were invited to participate in the research project which followed the guidelines of the university research ethics board for research involving human participants (see Appendix 1.). The school district and the principal of the school provided their permission for the study (see Appendix 2). As a collaborator in the project, the teacher was able to maintain autonomy over the curricular activities her students completed. The teacher described the composition of the class as; "twenty-five thirteen to fourteen-year-old grade eight students with diverse learning needs". A letter asking for informed consent was sent to parents and guardians (see Appendix 3.). All but three families provided consent. The teacher placed students for whom consent was not obtained in the same group, which allowed them to complete all activities, however, their participation was not video or audio recorded.

Data Collection

Collection of data for this study followed a "naturalistic" approach as described by Guba and Lincoln (1985) in the sense that it attempted to uncover what was done and said in the everyday ("natural") setting of the classroom. The purpose was to view events "through the eyes" of the participants. Rather than creating an experimental situation for the purposes of research, the researchers attempted to minimize disruption of the class as much as possible and allow the teacher to maintain autonomy of her class. The research group worked within the context of the activity, the context of the curriculum addressed, as well as the teachers plan, which had been developed in the interest of her students and their learning. The teacher dictated the activities at each station, the lay out of the stations, the group composition as well as the assessment which followed the activities that day.

Two video cameras and an audio recorder were placed to record participant conversations at station 1 while students completed their work and conversed with the facilitator and each other. One camera was situated in front of the participants, to record sound, gestures and facial expressions throughout each groups' remote laboratory access time. The other camera was placed behind the students to allow a view of the tablet and laptop screens they were using. The audio recorder was placed between the laptop and tablet (see Figure 6), acting as the main audio source for verbatim transcription. Transcription of audio recordings took place shortly after data collection to provide a verbatim transcription of the conversations for each of the six groups (see Figure 6). The cameras and audio recorder were turned off while the seventh group collected the data on their river site.

Figure 6. Location of Audio recorder and video cameras at station 1.



Data Analysis

Interaction analysis was first used by the research team to examine verbatim transcripts, video recordings and audio recordings, to identify examples of the three types of engagement and their frequency in student talk during the remote laboratory activity, using the precise definitions of each type of engagement that were established and are described above in the theoretical framework section. Counts of turns of speech were completed as counts of each type of engagement and were initially made to determine the position of episode on the video and audio recordings were marked. Since the definition of engagement being used in this study is an inclusive, overarching term, (Figure 1) a turn of speech that encompassed each type of engagement were not independent of each other. Therefore, a count of student turn that demonstrates disciplinary engagement in science or technology would also be counted as engagement. A count of productive disciplinary engagement would also be counted as disciplinary engagement as well as engagement.

When determining counts of types of engagement, it became evident that there might be a relationship between these counts and the amount of student and facilitator talk. To determine whether this was the case, the researcher conducted Pearson correlation tests. First, along with the counts of engagement, the amount of student talk (number of turns) and facilitator talk (number of turns), was recorded for each group. A facilitator was any individual helping to facilitate the activity, which included the researchers in the classroom with the students, the classroom teacher, and the scientist located in the laboratory with the TN-analyzer. The distribution of total counts of engagement, student turns and facilitator turns were tested for normality and since the distributions were normal, Pearson correlation tests were completed. A Pearson correlation test is a statistical analysis test which measures the linear correlation between two variables and will have values ranging from positive one to negative one (Agresti & Franklin, 2009). A value of positive one indicates a complete positive linear correlation, zero indicates no linear correlation, and negative one indicates a total negative linear correlation. Three Pearson correlation tests were completed to determine if a relationship exists between *student turns and engagement*, *student turns and facilitator turns*, as well as *facilitator turns and engagement*.

Conversation analysis was applied to examples where students demonstrated movement toward productive disciplinary engagement. The aim of this analysis was to look in depth at interactions between students and facilitator that occurred, to develop understanding of the ways that this type of engagement developed. Completion of this kind of analysis aims to develop understanding of how the participants in the turns interpret the discourse, rather than providing an interpretation by an analyst (Hsu, Roth, & Mazumder, 2009).

CHAPTER 4. Results

The purpose of this study was to determine in what ways engagement, disciplinary engagement, and productive disciplinary engagement are evident in student talk during a remote laboratory activity.

Evidence of engagement in the talk between facilitator and each of the six groups of students participating in the study is presented in three ways. First, it is presented through examples of each type of engagement, as well as the frequency of the types of engagement. Next, relationships between engagement and talk as determined through statistical analysis using Pearson correlations are presented. Finally, findings from conversation analysis of examples approaching productive disciplinary engagement are presented.

Evidence of Engagement, Disciplinary Engagement, and Productive Disciplinary Engagement

Definitions of engagement, disciplinary engagement, and productive disciplinary engagement, as modified from Engle and Conant (2002) were searched for in the transcripts and reviewed on the video and audio recordings. These examples were brought to the research group for discussion and confirmation according to the method of interaction analysis as indicated in the work of Jordon and Henderson (1995).

In this study, engagement is an inclusive, overarching term. Engagement is present when students demonstrate disciplinary engagement, as well as productive disciplinary engagement (Figure 1). In addition, there are examples of engagement that do not fall into either of the categories of disciplinary engagement or productive disciplinary engagement. In these cases of engagement, the topic is not directly associated with the task at hand (see Table 2).

Disciplinary engagement refers to engagement in the discipline the activity covers, in this case science. Similar to the overarching nature of engagement, disciplinary engagement is present when students exhibit signs of productive disciplinary engagement (Figure 1). Though interaction analysis, it became apparent that two types of disciplinary engagement were present, disciplinary engagement in science and disciplinary engagement with technology. Disciplinary engagement in science (DE Science) are episodes of student conversation that are in the context of the discipline of science, or times where a student demonstrates attributes of a person practicing science. A student demonstrating disciplinary engagement in technology (DE Tech) is engaged in the technology aspect of the activity and shows signs of interest in the technology facilitating the activity such as posing questions or comments about the technology.

A student that exhibits signs of productive disciplinary engagement (PDE) will show signs of disciplinary engagement in science, as well as engagement, and will also demonstrate intellectual progress. Intellectual progress is expressed when students are capable of using learned knowledge and applying it to new situations, problems, or tasks (Engle & Conant, 2002). The evidence found in this study were not classified as productive disciplinary engagement since it was not possible to definitely know whether the students were applying knowledge learned through this activity or previous knowledge. Therefore, the two groups which demonstrated intellectual progress were classified as movement toward productive disciplinary engagement (see Tables 7 and 8).

Table 2. Fragment of Discourse from Verbatim Transcript Containing Engagement

Turn	Speaker	Discourse
1.	Teresa	What types of nitrogen are there, that could be found in water?
2.	Tammy	Ummmm
3.	Mary	There is the one that made the frogs…(*inaudible)*. Types of nitrogen
4.	Teresa	Oh, those were parasites
5.	Mary	Oh. I went to the washroom, and then I kinda like
6.	Teresa	And you came back and there were deformed frogs (says laughing a little)
7.	Mary	then I came back and there was frogs and I was like What did I miss?
8.	Teresa	Then you were so sad that you missed that part because there was deformed frogs on the screen
9.	Mary	I didn't know what to think

Table 2. The facilitator in the fragment of discourse containing engagement is Teresa, and the students are Tammy and Mary.

In the example provided in Table 2, Teresa is the facilitator and the students are Tammy and Mary. This example is viewed as engagement that is neither disciplinary nor productive disciplinary engagement. The student is engaged in a light-hearted exchange that is tangential to the task at hand, which was to identify the types of nitrogen that could be found in the water.

Table 3. Fragment from Verbatim Transcript Containing Evidence of Disciplinary Engagement in Science

Turn	Speaker	Discourse
1.	Sam	Woah, it is peaking, it is going straight up. Oh, maybe not straight up. But, woah, it is growin,.. it is growin…
2.	Frank	It is past 11, 14,
3.	Sam	Woah, 14!
4.	Mark and Sam	*Laugh*
5.	Mark	Oh is that it's peak?
6.	Sam	Well, my prediction was right
7.	Sam	Oh, it is going down
8.	Sara	But that is signal, not concentration. That's signal
9.	Mark	OOhhh

Table 3. All speakers in the fragment of discourse containing evidence of disciplinary engagement in science are students. The turns counted as evidence of disciplinary engagement in science are turns one, three, six, and seven.

The students in the example highlighted in Table 3 are Sam, Frank, and Mark. They are at station one watching the analysis of their sample on the laptop screen that is providing remote access to the analytical instrument in the chemistry lab at the university, in real time. Sara is the facilitating scientist in the lab speaking with the students via Skype. This is an example of disciplinary engagement within science (DE Science). In the excerpt provided in Table 3, Sam is demonstrating signs of disciplinary engagement in science in turns one, three, and seven while watching the peak on the computer screen as well as in turn six where he demonstrates attributes of a scientist, by inferring from the incoming data.

Table 4. Fragment from Verbatim Transcript Containing Evidence of Disciplinary Engagement in Technology

Turn	Speaker	Discourse
1.	Teresa	K, I'm just going to help you because it is a little bit different for this one. So you have yours…. Oh, it didn't actually go into small farm it says, or campground. Exit this for a second, let's just go back
2.	John	I can *watch* what you guys are doing through this thing
3.	Sara	Press enter, I think, it'll update
4.	Teresa	OK
5.	John	This is scaring me
6.	Jane	Laughs
7.	John	It is in the moments that you forget what *skype* is

Table 4. The facilitators the fragment of discourse containing evidence of disciplinary engagement in technology are Teresa and Sara. The students in this fragment are Jane and John. The turns counted as evidence of disciplinary engagement in technology are turns two and seven.

In the example of disciplinary engagement in technology (Table 4), Teresa is the facilitator, John and Jane are students and Sara is the facilitating scientist in the chemistry lab at the university talking with the students via Skype. This is seen as an example of disciplinary engagement in technology (DE Tech) because the student is talking about the technology involved in the remote lab access, which allows him to watch what is happening in the lab and talk to the scientist via Skype. Turn two of Table 4 exhibits John explaining to his partners that he was able to watch remotely what they were controlling by looking at the tablet screen showing a video feed from a camera mounted on the ceiling of the chemistry lab at the university. John also demonstrates disciplinary engagement in technology by expressing how he forgot what Skype is and that they were on Skype in turn seven of Table 4.

Application of the definitions of engagement were applied to the transcripts in order to obtain counts of each type of engagement during the time students accessed the remote laboratory and collected data on their assigned water sample (see Table 5). As outlined in the definitions, engagement is an overarching term meaning that a count of disciplinary engagement in column three of Table 5 will also be included as a count of engagement in column two. This inclusion also affects counts in that a count of productive disciplinary engagement in column five will also be included as a count of disciplinary engagement in science (column three) and engagement (column two).

Table 5. Summary of Engagement Counts During Remote Laboratory Activity

Group	Engagement	DE Science	DE Tech	Movement Toward PDE
1	76	20	11	0
2	48	9	6	0
3	86	20	4	2
4	122	28	20	2
5	110	33	8	0
6	23	5	7	0
Totals	*465*	*115*	*56*	*4*

Table 5. A count of productive disciplinary engagement is also counted as a count of disciplinary engagement in science, as well as a count of engagement.

The results in Table 5 demonstrate evidence that students were engaged while completing the remote laboratory activity. The frequency of each type of engagement differed for each group. Two out of the six groups demonstrated movement toward productive disciplinary engagement.

Relationships between Engagement and Talk

Along with the counts of types of engagement, the total count of student turns in the conversations for each group was completed as well as counts of total turns of facilitator talk (see Table 6). The counts of student talk were completed by counting each turn when a student spoke. Counts of facilitator talk was completed in a similar fashion, where a facilitator was any individual helping facilitate the activity, so is summed across all facilitators present.

Table 6. Summary of Engagement, Facilitator, and Student Turns, during the Remote Laboratory Activity

Group	Engagement	Student Turns	Facilitator Turns	Total Turns
1	76	82	68	150
2	48	51	64	115
3	86	93	83	176
4	122	140	87	227
5	110	116	71	187
6	23	33	39	72
Totals	*465*	*515*	*412*	*927*

Table 6. The column of Engagement is the sum of all counts of engagement, Student Turns is the sum of all counts of student turns (including non-engagement turns), and Facilitator Turns is the sum of all counts of any facilitator turns.

Counts of engagement, student turns, and facilitator turns were tested for normality in order to complete Pearson correlation tests. All three items show normal distribution. Pearson correlation tests were performed to determine if there is a correlation between *engagement and student talk*, *student talk and facilitator talk*, as well as *engagement and facilitator talk*. Each test demonstrated a positive correlation between the items being compared ($r(6) = 0.993$, $p < 0.001$; $r(6) = 0.856$, $p < 0.0300$; $r(6) = 0.872$, $p < 0.0230$ respectively). The results of a Chi-Square Goodness-of-Fit test on the observed counts of student talk revealed that the expected value of student talk for each group if the distribution was random would be 85. 833. Groups three, four, and five talked more than expected (93, 140, 116 turns respectively), while groups one, two, and six talked less than expected (82, 51, and 33 turns respectively) ($x^2(5, N = 515) = 92.2117$, $p < 0.001$). The results regarding the relationship between engagement and talk will be addressed in the discussion section.

Examples of Movement Toward Productive Disciplinary Engagement

In order to look in depth at the two examples judged as approaching productive disciplinary engagement to investigate further *how* these instances came about, conversation analysis (Sacks et al., 1974) was completed. First, an adapted version of the Jeffersonian system notation (Atkinson & Heritage, 1984, see Appendix 4) was applied to episodes that included movement toward productive disciplinary engagement (Table 7 and 8). This notation allows us to see turn pairs and how turns were taken up by participants in the conversations.

Table 7. Fragment from Verbatim Transcript of Group Four Moving toward Productive Disciplinary Engagement

Turn	Speaker	Discourse
1.	Jane	Oh ya, >beca[use it all goes into the river<
2.	Helen	[Ya]
3.	Teresa	°It's just the waste water group° So-I guess you will have to have a discussion]
4.	John	[No::::o (*looking in the direction of the laptop)*
5.	Teresa	[So-why do you think- why you think maybe-So now the river is actually the smallest-so why do you think it is the smallest↑
6.	Helen	I don't know but we thought it would be the biggest because everything run:ning into it↑
7.	Jane	=Ya:[a
8.	Helen	[Cause it is the middle of the river
9.	Teresa	OK - but what about the fact that it is actually moving water↑ -Cause if you think about the sides of a river↑
10.	Helen	Mh:m
11.	Teresa	things kind of- sometimes things can get kind of trapped
12.	Jane	=O::oh::h ya::a - that makes sense.

Table 7. The facilitator in the fragment of discourse of group four is Teresa. The students in this fragment of discourse are Jane, Helen, and John. The turns one and six are counted as evidence of movement toward productive disciplinary engagement. Turn 11 is an evaluative turn.

In the example in Table 7 Teresa is the facilitator while Helen, Jane, and John are students. They are discussing the total nitrogen content of their groups sample that they have just observed on the laptop that is connected remotely to the analytical instrument in the chemistry lab, at the university. Their sample is from the waste water treatment plant. They are discussing their results in relation to their predictions.

Looking at Table 7, turns five to eight reveal that turn five, initiated by the facilitator Teresa, is taken up as a question by Helen and Jane who respond in turns six to eight. Teresa's question refers to the finding from the analysis that the water sample from the middle of the river is the smallest value reported thus far, indicating the lowest level of total nitrogen. In her question Teresa asks, "why do you think it is smallest?" In her response in turn six, Helen indicates that the finding was unexpected when she says, "we thought it would be the biggest" and she indicates why that had been their prediction when she says, "everything running into it". In turn seven, Jane agrees and in turn eight Helen continues her response. According to our definition of productive disciplinary engagement (see p. 25 - 26), Helen demonstrates movement toward productive disciplinary engagement by applying previous knowledge to explain why her group thought the middle of the river would contain the highest amount of total nitrogen (turn six, Table 7).

Table 8. Fragment from Verbatim Transcript of Group Three Moving toward Productive Disciplinary Engagement

Turn	Speaker	Discourse
1.	Emily	It was like, gradual, gradual, and then go:od[by:e (*Emily looks at the laptop, then to Teresa. She moves her arm in the air to show the general shape of the curve)*
2.	Teresa	[It is hu:ge *(Teresa is leaned in and looking at the laptop)*
3.	Emily	I think we will definitely have to change our prediction (*turns toward Teresa while speaking, then turns toward Karen*)
4.	Emily	Laughing] (*looks towards Karen)*
5.	Teresa	[Maybe (*looking at the laptop)* Um, - and then so usually (*points at laptop*) - so the other groups too - Cause it is on the (*points at laptop*) - you didn't umm, zoom in even did you even↑ (*looking at Emily while pointing at computer*)
6.	Emily	=No *(looks at Teresa, then glances toward Karen/ tablet)*
7.	Teresa	Ok. So that is fine cause you can↑ but umm (*leans in and uses right hand on laptop mouse)* °we can actually put it lets see do this click↑ (*brings hand away from lap top*) and then go and it'll say and go default°(*points at laptop with right hand*) and let's just see if it shrinks↑ Ok, so it is still pretty (*points at laptop)* - this is the default and so everyone else so far↑ (*takes a step back and uses hands as emphasis*) just so you know what other groups looked like at the table (*points at computer)* - It was like a little baby bump (*moves right hand up slightly and back down slightly in the air)* You could barely even see it

		So (*points to computer*)
8.	Emily	=I think we will change our prediction (laughs) (*looking at Karen)*
9.	Karen	°*Inaudible*° *Karen says something (can see lips move on video)* *(Karen was looking at Emily, then turned, and leaned toward the tablet and began to touch the tablet screen with her right hand)*
10.	Emily	That's:s - pretty cool (*looking at laptop)*
11.	Teresa	Mm::Hh::mm so why- what was your prediction fo:or↑ (*stands upright and crosses her arms)*
12.	Emily	°Um::m like ah over there↑° *(turns her head to the right and raises right arm to point in that direction*)
13.	Teresa	=Which one did you guys think was going to be the most↑ *(standing with her arms crossed and looking at Emily)*
14.	Emily	=ah:h we thought it was going to be um:m the middle of the river. *(looking to the right at the class predictions, at the end of her turn of speech, she turns her head to look up at Teresa)*
15.	Teresa	= >The middle of the river< (*nods head*) Ok so:o do you think this (*points at the laptop*) is going to be more than the middle of the river↑
16.	Karen	=[[Ya]] *(looking in the direction of the laptop)*
17.	Emily	=[[Ya]] *(facing the laptop and leans back slightly and tilts her chin up slightly at the same time, then leans forward to the original position)*

18.	Teresa	=K, and why do you think that mi:ght be↑ *(standing with her arms crossed)*
19.	Emily	=Um:m just because - um it's probably going to have a higher concentration (*shrugs shoulders and turns to face Teresa and Karen more*) cause like everything flowing (*moves left arm in the air toward computer*) to into the middle of the river but it is li-ke °more dis:spersed° (*moves both of her hands away from her body, and back to middle – circle*) but like on the farm (*both hands motion in the direction of the laptop*) cause the cows have free range to just go like go and come (*moves both hands toward the laptop and back to herself placing hands together)* -so it is more like °concentrated (*moves both hands in front of herself, and back to the middle a couple of times – circle)* in that area° (*scratches her right eyebrow with her right hand*)
20.	Teresa	*(standing with her arms crossed)* =Mhm::m and so - what are like some things that farms -and cows (*moves right hand while talking*) [in terms of the nitrogen↑] (*moves right hand to her chin*)
21.	Emily	[Um:m they have] - have fertilizers carry nitrogen - manure have nitrogen *(looking at Teresa while she talks and use her hands to emphasize points)*
22.	Teresa	=O:h↑ OK↑ [so *(standing with her left hand holding her right bicep and her right hand holding her chin)*
23.	Emily	[if all of that stuff is at a farm- *(looking at Teresa while she talks and uses hand gesture while talking)*
24.	Teresa	=Ya - and it said the cows can go to the river↑ *(standing with her arms crossed and looking at Emily)*

25.	Emily	=Ya *(looking at Teresa)*
26.	Teresa	Ok *(nods head)* *(standing with arms crossed, nods her head and is looking at Emily)*
27.	Emily	- so they can just come and go as they please *(looks at Teresa, then back to the laptop and moves her left hand back and forth while talking)*

Table 8. The facilitator in the fragment of discourse of group three is Teresa. The students in this fragment are Emily and Karen. Turns 19 and 20 are counted as movement toward productive disciplinary engagement. A clarification question (by facilitator)-response (by student) pattern develops in turns 11-25 and acknowledgement turns are used by the facilitator in turns 22 and 26.

In the example of group three in Table 8, Teresa is the facilitator while Emily and Karen are students. Like the example in Table 7, Teresa and the students are discussing their group results of total nitrogen content in their sample, which is being viewed on the laptop that is connected remotely to the analytical instrument in the chemistry lab. Their sample is from the location of small farm. Like the group in the example in Table 7, they are discussing their results in relation to their predictions. Emily initiates the conversation in turn 1 when she describes in words and gestures the magnitude and shape of the peak that the group sees on the computer screen. Teresa responds in turn two remarking that the peak is huge. As occurred for group four in Table 7, in turn three Emily remarks that the group will need to change their prediction. What transpires is a series of *clarification question–response* turn pairs with Teresa asking the questions (turns 11, 13, 15, 18, 20, 24) and Emily and sometimes Karen responding (12, 14, 16, 19, 21, 25). In addition to clarification questions, Teresa's turns are at times acknowledgments (22, 26) to which Emily responds by continuing.

In turn one of the fragment of verbatim transcript in Table 8, Emily demonstrates engagement in the discipline of science by recognizing the significance of the incoming data and that her group will need to adjust the predictions it previously made. Emily demonstrated an interest with the incoming results and demonstrated characteristics of a scientist by recognizing their group needed to adjust their initial predictions.

This excerpt of group three also highlights movement toward productive disciplinary engagement through Emily's intellectual progress in explaining why the incoming data makes sense (turn 19 and 21, Table 8).

Summary of Results

Examples of student engagement, disciplinary engagement and engagement approaching disciplinary engagement were evident in the talk between students and facilitators during the remote laboratory activity. The frequency of engagement and the types of engagement differed for the six groups of students in the study. Positive correlations were demonstrated between amount of engagement and amount of talk were established. The positive relationships established in this study were between *engagement and student talk*, *student talk and facilitator talk*, and *engagement and facilitator talk*. Finally, conversation analysis suggested that dialogic discourse between the students and facilitators may support the progression of a student engagement toward productive disciplinary engagement.

CHAPTER 5. Discussion

A common objective amongst most educators is to increase student engagement in the classroom, as a way to enhance meaningful learning. It has been demonstrated internationally that student engagement in STEM subjects has declined, which in turn has impacted the number of students pursuing STEM-oriented education and careers (OECD, 2008). It is important to increase engagement in STEM topics with students prior to high school because students tend to demonstrate which content areas they prefer in elementary and middle school years (Christensen, et al*.,* 2015). It is therefore essential for educators to facilitate activities that will increase engagement in STEM topics. The prior study of this remote laboratory activity is evidence of one research paper which provides middle school students access and use of a remote laboratory activity with an analytical instrument (Stewart, et al., 2017). The study conducted by Stewart (2017) was completed within the same context, group of participants, as well as the activity of this study. The results from Stewart (2017) were based on student survey results following completion of the remote laboratory activity. The students reported that they were engaged in the remote laboratory activity, they were engaged with the technology aspects that facilitated the activity, and they were engaged in the content area of chemistry (Stewart, et al., 2017). The results of this study are important as they show evidence of engagement in the talk of middle school students' during the remote laboratory activity and they show that some students demonstrate movement toward productive disciplinary engagement while engaged in the activity. Providing middle school students with opportunities to increase their engagement in STEM topics through activity such as this, may increase the probability that they will pursue a STEM oriented education and career (Christensen, et al., 2015).

In Engle and Conant's productive disciplinary engagement model (2002) they propose four principles which must be present for productive disciplinary engagement to occur. It is these four principles that facilitate students' journey to establishing intellectual progress and productive disciplinary engagement. The four principles of PDE were described in detail in the literature review chapter: problematizing, authority, accountability, and resources.

Upon looking at the inquiry project that is the context of this study, there is evidence of all four guiding principles. The teacher of this class was able to devise a situation in which the students had to *problematize* what was presented to them when they were asked to tackle an intellectual problem of deciding where a community should be built along a river. Through classroom research using *resources* provided to them, the students ranked the seven sites along the river from highest to lowest levels of nitrogen. The BC-ILN provided an additional *resource* in which the students were able to use a TOC-TN analyzer to measure the amount of nitrogen in their assigned river site. Students were given *authority* by having a river site assigned to them. Each group of students was held *accountable* to the entire class through the necessity of sharing and reporting the level of nitrogen at their assigned river site. With the incoming of new data, the students maintained an *authority* over their initial predictions when provided with an opportunity to change their predictions. Since the circumstances of the activity were fictional, the students' samples were not real in that they were not actually collected from the sites they represent. The samples that students tested were produced in the lab by a

BC-ILN chemist to simulate the levels of nitrogen that that would naturally occur at each site. Prior to making the water samples, the chemist reviewed literature to determine what levels of nitrogen occur in a river with the particular sites suggested. In the context of the activity was real, students would have been able to broaden their authority in the activity by actively going out to collect their own sample.

Knowing that the four principles were present during the remote laboratory activity, it is not surprising that signs of engagement and disciplinary engagement were evident in all of the participating groups (Table 5.), with two out of the six groups showing movement toward productive disciplinary engagement (Table 5.).

Results of statistical analyses, which further analyzed the data presented in Table 6, showed a significant and positive correlation between *engagement and student talk*, *student talk and facilitator talk*, as well as *engagement and facilitator talk*. The correlation results show engagement increases with student talk. This relationship between student talk and engagement makes sense; when there are more opportunities to measure engagement, counts of engagement will naturally increase. Interestingly, the Pearson's correlation revealed that when there is an increase of facilitator talk, there is an increase in student talk (Table 6). Although a correlation cannot indicate a causal relationship, these results, together with the conversation analysis results, suggest when the facilitator asks questions, and acknowledges student turns verbally, student talk will be promoted and increase. Knowing a positive relationship between facilitator talk and student talk exists, it is not surprising that a positive correlation between facilitator talk and student engagement is evident. If an increase in facilitator talk promotes more student talk, there will be more occasions for engagement, thus increasing engagement counts.

The results of a Chi-Square Goodness-of-Fit test on the observed counts of student talk revealed that three out of the six groups talked more than expected, and three groups talked less than expected. As previously mentioned, the amount and ways in which the facilitator talks with each group of students may have had an effect on the amount of student talk. Another aspect that may affected student talk could have been the personality of the students, as well as the composition of the groups. Some students are naturally quiet and shy, and some of the students may not have been used to working with the other members of their assigned group, which resulted in less student talk. These results suggest further potential of the remote laboratory activity to facilitate productive disciplinary engagement with middle school students.

Previous research and literature establish common patterns of speech that arise between students and teacher. A common discourse pattern in a classroom is the initiation, reply, and evaluation form (I-R-E) (Mehan, 1979), which can restrict student speech as the students do not sense another opportunity to talk following an evaluation comment (Cazden, 2001; Mercer & Dawes, 2014). A discourse pattern which promotes more natural and open pattern includes Feedback, as in the Initiation-Response-Feedback (I-R-F-R-F-R-F) pattern, that is found when the teacher utilizes open-ended questioning (Mercer & Dawes, 2014; Alexander, 2010).

Results of conversation analysis of the examples approaching productive disciplinary engagement explores in more depth how productive disciplinary engagement was produced (Tables 7 and 8). These examples demonstrated the ways engagement, disciplinary engagement, and movement toward productive disciplinary engagement were evident in student talk during the remote laboratory activity. A comparison of results from group three and four (Tables 8 and 7 respectively), which showed progress toward productive disciplinary engagement, indicates how the facilitator contributed to the conversation. With group three (Table 8) the facilitator used several acknowledgement turns and clarification questions when interacting with Emily (Rees, Mba, & Roth, 2018). Acknowledgement turns by the facilitator and or teacher are turns in which they simply for example "yes" or "oh yeah" in acknowledgment. Prior research indicates that such acknowledgement turns can promote further contribution of speech by the student (Rees, Mba, & Roth, 2018). This is evident in this study, for example in turn 22 (Table 8). By using acknowledgement turns, the facilitator presented an opportunity for Emily to expand on the topic, in this example the acknowledgement turns act as the Feedback in an I-R-F-R-F-R-F pattern. The utilization of clarification questions contributed to the conversation in a similar fashion as the acknowledgement turns, in that they facilitate student speech further. The clarification questions differ from the acknowledgment turns in that they are a question. These questions allow the student to elaborate further on the topic being discussed, and in turn, lead to a further demonstration of their understanding and engagement in the topic itself (Rees, Mba, & Roth, 2018). Clarification questions were a type of Feedback presented to Emily that provided another encouraging platform for Emily to further the conversation (Table 8: Turns 11, 13, 15, 18, 20, 24). Use of this pattern may have led Emily to demonstrate progress toward productive disciplinary engagement. Additionally, when a student in group four was not able to answer a question, the facilitator answered the question rather than providing clarification questions and acknowledgement turns (Turn 11, Table 7). In this example, rather than providing further feedback, answering the question acted as an Evaluation as in the I-R-E pattern. In the I-R-E pattern it is common to observe no further contribution to the conversation by students following an Evaluation response (Mehan, 1979; Cazden, 2001). In turn 11 in Table 7., the facilitator answers their own question, Jane responds to the facilitator in turn 12, however, the conversation does not continue and there is no evidence to demonstrate whether the students in group four understood the comments by the facilitator. The actions of the facilitator may have prevented students in group four to demonstrate further progression in their understanding of the topic, therefore reaching productive disciplinary engagement. The facilitator may have halted further discussion as the students did not sense the need for further discussion on the topic. With group three (Table 8), there is no evidence of such an I-R-E pattern between the facilitator and students. Further comparison of the patterns of speech between the two groups (Tables 7 and 8) reveal clarification questions and acknowledgement turns (Feedback) used extensively with group three (Table 8). The patterns of speech between the students and the facilitator may have impacted how the students were able to demonstrate their progress in their understanding of the topic and show movement toward productive disciplinary engagement. In turn, the patterns may have influenced students' abilities to demonstrate engagement. If the facilitator had been cognisant of the implications of discourse patterns, more students may have been provided with the opportunity to demonstrate their knowledge, as well as their engagement. Since the conversations between facilitator and students transpired in a natural way and were not scripted, the direction of each conversation was slightly different for each group of students.

Limitations of Study

The nature and context of this study presented several constraints to how the study could be conducted. The research group collecting data for this study were taking a naturalist approach (Lincoln & Guba, 1985) meaning that the researchers as much as possible were determined not to interfere with the teachers and students work. This allowed the teacher to maintain autonomy of her class, where she dictated the activities that her students would complete at the stations, the lay out of the stations, the composition of groups as well as the assessment which followed the multiday activities. The research group made sure to work within the context of the curriculum addressed, as well as the teachers plan, which had been developed in the interest of her students and their learning. The teacher had the autonomy and created the groups to fit her plan and her time available. How groups were created, and therefore the number of groups accessing the remote laboratory, was limited to six. If students were placed in groups of two, the number of groups accessing the instrument would have increased to nine, therefore increasing the data and sample size collected. This would have impacted the teachers plan.

In addition, the context of the analytical instrument being used to test levels of nitrogen takes limited time to complete the measurement of the sample and the output of data; therefore, the video and audio recordings of students using the analytical instrument remotely was limited to this time period, which is restricted to the time the instrument takes to analyze a water sample. The conversations during the activity offered a snapshot of student engagement and further engagement might have occurred if there was more time to continue the conversation.

Other aspects that should be considered are the influence of the researchers on the students and facilitators. The presence of the video and audio recording could impact natural talk which could in turn impact evidence of student engagement. There may have been instances where students wanted to converse in dialogue with each other, or the facilitator but their behaviours were altered in the presence of the audio and video recorders, which could have had an effect on the evidence of engagement. In addition, it is important to know that student engagement may be affected by how students are assessed during and after the remote laboratory activity.

Future Work

This research study has prompted new questions which can be further investigated in future research.

A study of gestures could be added to the conversation analysis throughout the remote laboratory activity. Gestures were documented in this study and they were clearly of interest but due to time constraints they were not included in the analysis. For example, gestures such as pointing to the tablet screen or turning in reaction to a sound produced by the instrument could also demonstrate disciplinary engagement with technology.

A study could be added that included deeper analysis of student and teacher feedback regarding the activity, for example through interviews, to determine whether students' perception of how engaging the remote laboratory activity was, correlated with the actual evidence of engagement at the time.

Another study could apply conversational analysis to examples of disciplinary engagement in science and disciplinary engagement with technology to determine if patterns are evident. One interesting question, for example, is whether disciplinary engagement in science occurs at the same time as disciplinary engagement with the technology. Another question is whether common themes in student talk arise in conversations exhibiting engagement in the discipline of science during the remote laboratory.

The impact on engagement of aspects of the remote laboratory activity could be examined. For example, it would be interesting to determine whether students are more engaged by the presence of a person in the laboratory versus no person and whether being able to hear the sound of the instrument vs. not being able to hear sounds from the laboratory influences student engagement.

It would be very interesting to conduct a case study of a full context like the inquiry-based project that was the context of this study.

Significance and Recommendations

The research conducted along with its results have significance at a local and global level. At the local level, this was an action research study aimed at helping the BC-ILN team which facilitated the remote laboratory activity, to have a greater understanding of how students become engaged through the science of the instrument and the technology they provide to the students. The recommendations that were an outcome of this study will help the team with future work with middle school students particularly. Following this study, the BC-ILN team would be encouraged to consider the impact of patterns of talk between the facilitator and students on types of engagement, as well as the positive correlation found between amount of student talk and facilitator talk. The results from this study provide insight to educators wishing to conduct remote laboratories in their classroom as it has demonstrated to be an engaging activity in which students are able to connect the curriculum they are learning to professionals in the field of science and equipment those professionals use. Educators wishing to use the remote laboratory activity with their students should view it not as a replacement of traditional hands on experiments, but rather as an opportunity for their students to be able to interact with people in the profession of science and use an analytical instrument which is nornmally far beyond the reach of the middle school or high school context. In addition, this action research study helped the teacher by demonstrating the presence of the four principles of the productive disciplinary engagement in the cross-curricular, inquiry-based project that she had created. At a global level, this study is the first to provide middle school students access to and use of a remote laboratory with a TOC-TN analyzer. The results of this study are significant as they show middle school students are capable of demonstrating movement toward productive disciplinary engagement while using an analytical instrument remotely.

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Appendix 1. Research Ethics Approval

November 22, 2016

Dr. Sharon Brewer
Faculty of Science\Chemistry
Thompson Rivers University

File Number: 100348
Approval Date: March 24, 2013
Expiry Date: September 30, 2017
Modification Date: November 23, 2016

Dear Dr. Sharon Brewer,

The Research Ethics Board has reviewed your modification for the project titled' Evaluating the Impact of Online Science Laboratory Experiences through the BC-ILN'. Your modification to add video/audio recording has been approved. You may begin the proposed research. This REB approval, dated March 24, 2013, is valid for one year less a day: September 30, 2017.

Throughout the duration of this REB approval, all requests for modifications, renewals and serious adverse event reports are submitted via the Research Portal. To continue your proposed research beyond September 30, 2017, you must submit a Renewal Form before September 30, 2017. If your research ends before September 30, 2017, please submit a Final Report Form to close out REB approval monitoring efforts.

If you have any questions about the REB review & approval process, please contact the Research Ethics Office via 250.852.7122. If you encounter any issues when working in the Research Portal, please contact the Research Office at 250.371.5586.

Sincerely,

[https://tru.researchservicesoffice.com/logo/ESignature3.jpg]
Andrew Fergus
Chair, Research Ethics Board

Appendix 2. School District 73 Research Approval

SCHOOL DISTRICT NO. 73 (KAMLOOPS/THOMPSON)

1383-9th Avenue, Kamloops, B.C. V2C 3X7 • Telephone: (250) 374-0679 • Fax: (250) 372-1183

May 16, 2017

Susan Lidster
805 TRU Way
Kamloops, BC V2C 0C8

By email: slidster@tru.ca

Dear Ms. Lidster;

RE: RESEARCH PROJECT

I am writing to approve your request to conduct a research project involving students at Brocklehurst Middle School enrolled in the Explorations Program. I understand that you and your research team will be video recording students while they are engaged in the online laboratory experience. Parental and student consent will be required for all participants and students who do not consent will not be video recorded.

Also, I have attached a copy of Board Policy #809.1 for your reference. Please review this policy before conducting your research.

Good luck with your project.

Sincerely,

Alison Sidow
Superintendent of Schools

AS: dh
Attach.

cc: B. Hamblett, Assistant Superintendent
V. Mochikas, Principal – Brocklehurst Middle School

WORKING TOGETHER FOR QUALITY PUBLIC EDUCATION

Appendix 3. Letter to Participant's Guardian

THOMPSON RIVERS UNIVERSITY

Dear Parent/Guardian:

During this semester as part of their School name Class name, your child/ward will be doing a chemical analysis activity using an instrument from Thompson Rivers University over the internet from their school. This activity is made available by a research study exploring the use of scientific instruments over the internet by students for chemical analysis. This study, led by TRU Faculty Dr. Sharon Brewer, Dr. Bruno Cinel, Dr. Carol Rees and Dr. Susan Lidster is interested in investigating how access to instruments over the web impacts student interest, enjoyment, and engagement in science. This study is a part of the research project: "Evaluating the Impact of Online Science Laboratory Experiences through the BC-ILN". We would also like permission to record video and audio of the students and teacher preparing for and doing the chemical analysis activity and answering questions about the activity. The researchers will examine the recordings to gain information about student interest, enjoyment and engagement and how students identify themselves as scientists. All videos and audio recordings will be transcribed and pseudonyms will be used, and only transcripts will be shared in research papers. Only the research team and participants will view and listen to the video and audio recordings. The recordings will be transcribed into words by our research team who has signed confidentiality agreements. All identifying information will be removed.

You are being asked to give permission for your child/ward to complete the anonymous survey during their scheduled class. Survey completion should take no more than 5 minutes. The survey will be done in their class, after they have completed the activity. You are also being asked for permission to have your child/ward have audio and video recordings taken of them preparing for, participating in, and discussing the activity in their regular class. This information will be used to assess the experience.

By giving permission for your childs/wards participation, you agree to have the anonymous survey responses and transcripts compiled with those of other participants and evaluated by the researchers involved in this project. No identifying information will be collected with the survey responses. Your Teacher will not have access to any individual responses; they will all be kept confidential. Students may refuse to participate, hand in a blank survey or withdraw participation in this survey at any time prior to submission of the survey without consequence. There will be no impact on grade or evaluation of performance in the class. Completed surveys will be placed in a provided envelope by a neutral third party, which will then be sealed and returned to us. Survey data will be compiled and then surveys will be stored in a locked filing cabinet for seven years, then shredded and destroyed. The video and audio recordings will be transcribed and then stored in a locked filing cabinet for seven years, then shredded and destroyed. The study has passed the Thompson Rivers University ethical review process and been accepted by School District 73 and the Principal of the school. The results from this study will be published in professional journals and conferences. The names of teachers and students will be replaced with pseudonyms and no identifying information will be given.

If you give permission for your child/ward to participate in the survey, participate in video and audio recordings, and be anonymously included in the study's results please indicate this on the attached form. Students who do not do the survey or who do not participate in video or audio recordings will still participate in the same activity. If you have any questions or wish to receive the results of the study after completion, please contact Dr. Sharon Brewer at 250-371-5548. If you wish to register a complaint about the study please contact us and/or any of the following people.

Principal Name School Phone number	Sharon Brewer & Bruno Cinel Researchers Thompson Rivers University sbrewer@tru.ca 250-371-5548	Carol Rees & Susan Lidster Researchers Thompson Rivers University crees@tru.ca 250-828-5004	Tom Dickinson Dean, Faculty of Science Thompson Rivers University tdickinson@tru.ca 250-371-5906	Airini Dean, Faculty of Education and Social Work Thompson Rivers University airini@tru.ca 250-320-5552

Thank you for your consideration.

Sincerely,

Sharon Brewer, Bruno Cinel, Carol Rees, Susan Lidster Thompson Rivers University

Appendix 4. List of Transcript Notation Symbols

Transcript Notation Symbols	Definition
:	A colon indicates an extension of the sound or syllable it follows (more colons prolongs the stretch)
=	Where there is no interval between adjacent utterances, the second being latched immediately to the first (without overlapping it), the utterances are linked together with equal signs
> <	When part of the utterance is delivered at a pace quicker than the surrounding talk, it indicated by being enclosed between “less than” signs
° °	A degree sign is used to indicate a passage of talk which is quieter than the surrounding talk
[ ] [ ]	When overlapping utterances do not start simultaneously, the point at which the ongoing utterance is joined by another is marked with a single left hand bracket, linking an ongoing with an overlapping utterance at the point where overlap begins
-	A short untimed pause within an utterance is indicated by a dash
↑	Marked rising in intonation are indicated by an upward pointing arrows immediately prior to the rise.